Geographic Network Visualization Techniques:A Work-In-Progress Taxonomy

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Sarah Schöttler[1], Tobias Kauer[1], and Benjamin Bach[1]

University of Edinburgh, UK

Abstract. This poster presents a survey of visualization techniques for geographic networks. Based on 60 techniques, we provide an initial taxonomy based on categorizing each technique across four facets: how the geographic aspect is represented, how the network aspect is represented, how these two visual representations are integrated, and whether the technique relies on user interaction. The current collection can be found online: `https://geographic-networks.github.io`.

Keywords: Geographic networks · survey · taxonomy.

1 Scope and Methodology

Geographic network data describes the relationships between geolocated entities. Examples include airports connected by commercial flights, trading networks, migration, geographic social networks or public transport networks in cities. Yet, visualizing these networks remains challenging: overlap and clutter frequently make visualizations difficult to read or even misleading. Often, there is a trade-off between computational complexity, visual quality, and the specific task at hand (analyzing geographic locations, analyzing network topology, correlating both, etc). *No taxonomy specific to these techniques exists.*

To qualify for inclusion into our survey, a paper has to either be focused entirely on geographic networks, or, at a minimum, demonstrate its applicability to geographic networks with a case study. Techniques that can theoretically be applied to geographic networks, but do not visualize the geographic aspect of the network, were not considered. Papers come from different venues: IEEE VIS, ACM CHI, EuroVis, PacificVis, and Graph Drawing. Our search resulted in 191 papers which we manually narrowed down to 40. Through additional manual search, the number increased back to 60 papers/techniques.

2 Taxonomy

A—Geographic Representation. This facet describes how the geographic aspect of the network is represented visually. We found visualizations to differ in the way they distort and abstract that geographic representation: **Map** is the least distorted technique [12, 4, 15, 14, 23, 12]. **Distorted map** includes any visualization that is still recognizable as a map, but distorted beyond the distortion

introduced by the map projection [1, 15, 5, 19]. **Abstract** techniques represent geography in some non-geographic (abstract) form such as grouping nodes in a circular layout [11].

B—Network Representation. Initially, we thought to categorize according to the type of visualization. However, we quickly found that approx. 90% of all techniques use node-link diagrams, some matrices. Thus, we decided to again look for 'abstraction' in the network representation. Since a network consists of nodes *and* edges, we classify techniques along both axes: node abstraction and edge abstraction. The node representation is *explicit* when nodes are shown as points in a node-link diagram and *abstract* if not; the edge representation is *abstract* when edges are shown different than links in a node-link diagram. Another way of looking at this is whether it is theoretically possible to extract the precise network data from the visualization—independent from clutter due to potential overlap and occlusion. **Explicit nodes & explicit edges:** Includes all techniques that explicitly visualize nodes and edges: edge bundling, edge routing, 3D globes etc. [12, 14] **Explicit nodes & abstract edges:** Techniques in this category explicitly show the nodes of the network, but use abstract means of showing the connections between them. Examples include omitting edges [1] or using alternative representations [4]. **Abstract nodes & explicit edges:** Abstracting the nodes but not the edges, e.g. aggregating nodes [8, 7]. **Abstract nodes & abstract edges:** Both nodes and edges are abstracted, e.g. OD maps or aggregating both nodes and edges [21, 3].

C—Integration describes how geography and topology are integrated in the visualization, simplifying the approach in [10]. **Geography-as-basis**: The majority (44) of the surveyed visualization techniques use the geography representation as their basis and overlay a network visualization [8, 9, 3, 2, 21, 1]. A **balanced** integration is one where neither geography nor network are clearly dominant [13, 23]. **Network-as-basis:** Only one technique uses the network representation as its basis [11].

D—Interaction: classifies techniques into *none* [21, 13, 18], *optional* [4, 22], *required* [23, 6, 1], and *technique-is-interaction*; meaning that a technique is a pure interaction technique such as a fisheye lens [5], *EdgeLens* [19], link bundling [17], link plucking [20] or *Bring & Go* and *Link Sliding* [16].

3 Open Challenges

We are currently working to extend our collection and refine our taxonomy. However, many techniques remain to be explored; e.g., not taking interaction into account, there are 36 possible combinations of the different categories across facets of the taxonomy. Besides the groups discussed in the paper, we could identify the following open challenges for which we could find few or no techniques: **uncertainty** visualization of geographic positions and areas, **dynamic** geographic networks, **network-focused techniques** that preserve geography well, and precise **task and data taxonomies** that can inform future techniques, design spaces and interaction techniques.

References

1. Alper, B., Sümengen, S., Balcisoy, S.: Dynamic visualization of geographic networks using surface deformations with constraints. In: Proc. of the Computer Graphics International Conference (CGI), Computer Graphics Society, Petrópolis, Brazil (2007)
2. Andrienko, G., Andrienko, N., Fuchs, G., Wood, J.: Revealing Patterns and Trends of Mass Mobility Through Spatial and Temporal Abstraction of Origin-Destination Movement Data. IEEE Transactions on Visualization and Computer Graphics **23**(9), 2120–2136 (Sep 2017). https://doi.org/10.1109/TVCG.2016.2616404
3. Andrienko, N., Andrienko, G.: Spatial Generalization and Aggregation of Massive Movement Data. IEEE Transactions on Visualization and Computer Graphics **17**(2), 205–219 (Feb 2011). https://doi.org/10.1109/TVCG.2010.44
4. Boyandin, I., Bertini, E., Bak, P., Lalanne, D.: Flowstrates: An Approach for Visual Exploration of Temporal Origin-Destination Data. Computer Graphics Forum **30**(3), 971–980 (2011). https://doi.org/10.1111/j.1467-8659.2011.01946.x
5. Brown, M.H., Meehan, J.R., Sarkar, M.: Browsing Graphs Using a Fisheye View (Abstract). In: Proceedings of the INTERACT '93 and CHI '93 Conference on Human Factors in Computing Systems. pp. 516–. CHI '93, ACM, New York, NY, USA (1993). https://doi.org/10.1145/169059.169474, event-place: Amsterdam, The Netherlands
6. Cox, K.C., Eick, S.G., He, T.: 3d Geographic Network Displays. SIGMOD Rec. **25**(4), 50–54 (Dec 1996). https://doi.org/10.1145/245882.245901
7. Elzen, S.v.d., Wijk, J.J.v.: Multivariate Network Exploration and Presentation: From Detail to Overview via Selections and Aggregations. IEEE Transactions on Visualization and Computer Graphics **20**(12), 2310–2319 (Dec 2014). https://doi.org/10.1109/TVCG.2014.2346441
8. Guo, D.: Flow Mapping and Multivariate Visualization of Large Spatial Interaction Data. IEEE Transactions on Visualization and Computer Graphics **15**(6), 1041–1048 (Nov 2009). https://doi.org/10.1109/TVCG.2009.143
9. Guo, D., Zhu, X.: Origin-Destination Flow Data Smoothing and Mapping. IEEE Transactions on Visualization and Computer Graphics **20**(12), 2043–2052 (Dec 2014). https://doi.org/10.1109/TVCG.2014.2346271
10. Hadlak, S., Schumann, H., Schulz, H.J.: A survey of multi-faceted graph visualization. In: Eurographics Conference on Visualization (EuroVis). vol. 33, pp. 1–20. The Eurographics Association Cagliary, Italy (2015)
11. Hennemann, S.: Information-rich visualisation of dense geographical networks. Journal of Maps **9**(1), 68–75 (Mar 2013). https://doi.org/10.1080/17445647.2012.753850
12. Holten, D., Wijk, J.J.V.: Force-Directed Edge Bundling for Graph Visualization. Computer Graphics Forum **28**(3), 983–990 (2009). https://doi.org/10.1111/j.1467-8659.2009.01450.x
13. Hong, S.H., Merrick, D., do Nascimento, H.A.D.: Automatic visualisation of metro maps. Journal of Visual Languages & Computing **17**(3), 203–224 (Jun 2006). https://doi.org/10.1016/j.jvlc.2005.09.001
14. Lambert, A., Bourqui, R., Auber, D.: 3d Edge Bundling for Geographical Data Visualization. In: 2010 14th International Conference Information Visualisation. pp. 329–335 (Jul 2010). https://doi.org/10.1109/IV.2010.53
15. Merrick, D., Gudmundsson, J.: Increasing the Readability of Graph Drawings with Centrality-based Scaling. In: Proceedings of the 2006 Asia-Pacific Sympo-

sium on Information Visualisation - Volume 60. pp. 67–76. APVis '06, Australian Computer Society, Inc., Darlinghurst, Australia, Australia (2006), https://dl.acm.org/citation.cfm?id=1151914, event-place: Tokyo, Japan
16. Moscovich, T., Chevalier, F., Henry, N., Pietriga, E., Fekete, J.D.: Topology-aware Navigation in Large Networks. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems. pp. 2319–2328. CHI '09, ACM, New York, NY, USA (2009). https://doi.org/10.1145/1518701.1519056, event-place: Boston, MA, USA
17. Riche, N.H., Dwyer, T., Lee, B., Carpendale, S.: Exploring the Design Space of Interactive Link Curvature in Network Diagrams. In: Proceedings of the International Working Conference on Advanced Visual Interfaces. pp. 506–513. AVI '12, ACM, New York, NY, USA (2012). https://doi.org/10.1145/2254556.2254652, event-place: Capri Island, Italy
18. Romat, H., Appert, C., Bach, B., Henry-Riche, N., Pietriga, E.: Animated Edge Textures in Node-Link Diagrams: A Design Space and Initial Evaluation. In: Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems. pp. 187:1–187:13. CHI '18, ACM, New York, NY, USA (2018). https://doi.org/10.1145/3173574.3173761, event-place: Montreal QC, Canada
19. Wong, N., Carpendale, S., Greenberg, S.: Edgelens: an interactive method for managing edge congestion in graphs. In: IEEE Symposium on Information Visualization 2003 (IEEE Cat. No.03TH8714). pp. 51–58 (Oct 2003). https://doi.org/10.1109/INFVIS.2003.1249008
20. Wong, N., Carpendale, S.: Supporting Interactive Graph Exploration Using Edge Plucking. In: Proceedings of IS&T/SPIE 19th Annual Symposium on Electronic Imaging: Visualization and Data Analysis (2007). https://doi.org/10.1.1.230.7985
21. Wood, J., Dykes, J., Slingsby, A.: Visualisation of Origins, Destinations and Flows with OD Maps. The Cartographic Journal **47**(2), 117–129 (May 2010). https://doi.org/10.1179/000870410X12658023467367
22. Yang, Y., Dwyer, T., Goodwin, S., Marriott, K.: Many-to-Many Geographically-Embedded Flow Visualisation: An Evaluation. IEEE Transactions on Visualization and Computer Graphics **23**(1), 411–420 (Jan 2017). https://doi.org/10.1109/TVCG.2016.2598885
23. Yang, Y., Dwyer, T., Jenny, B., Marriott, K., Cordeil, M., Chen, H.: Origin-Destination Flow Maps in Immersive Environments. IEEE Transactions on Visualization and Computer Graphics **25**(1), 693–703 (Jan 2019). https://doi.org/10.1109/TVCG.2018.2865192